PREPARING FOR VEG-04 AND VEG-05: IMPROVING PICK-AND-EAT FOOD CAPABILITIES FOR THE INTERNATIONAL SPACE STATION

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Human Research Program (HRP) Advanced Food Technology (AFT) Project Long Duration Food System Research Plan

- Continuing research to improve prepackaged system

- Supplement diet with pick and eat salad crops

Pick-and-eat salad-crop productivity, nutritional value, and acceptability to supplement the ISS food system

Aim: To examine light quality and fertilizer formulation on crop morphology, edible biomass yield, microbial food safety, organoleptic acceptability, nutritional value, and behavioral health benefits.

Team Components:

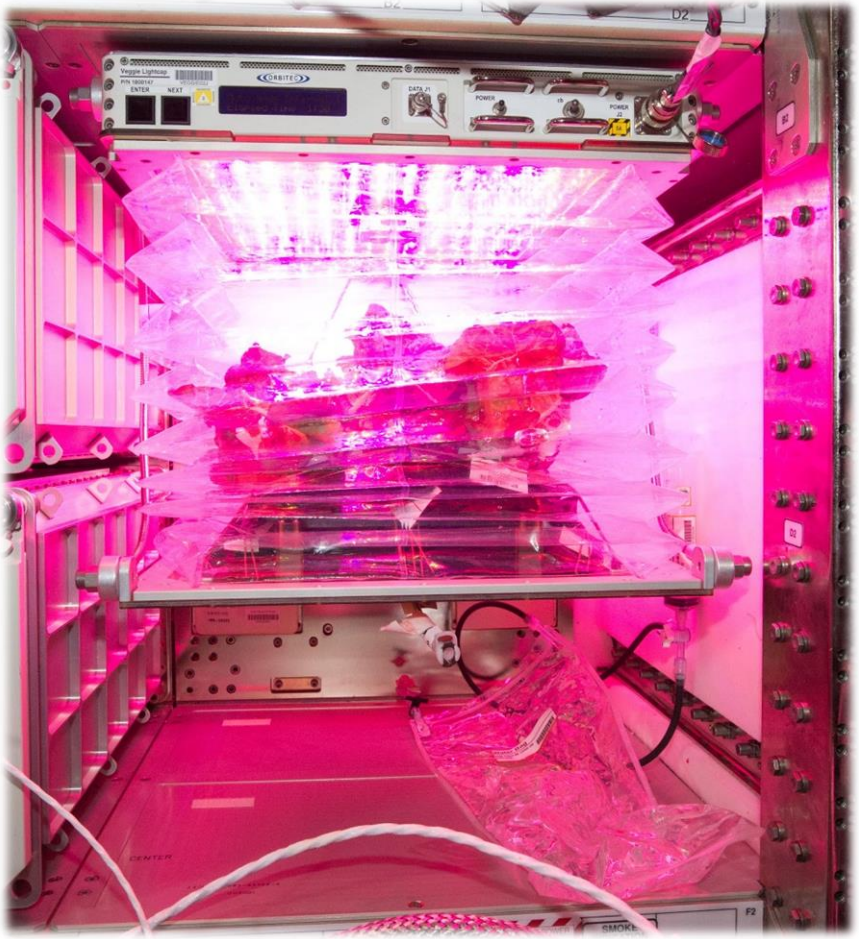
KSC: Food Crop Production, Microbiology

JSC: AFT, BHP, Statistics

Purdue: Food Crop Production

ORBITEC: Food Crop Production, Lighting, Software

Florikan: Fertilizer Consultants



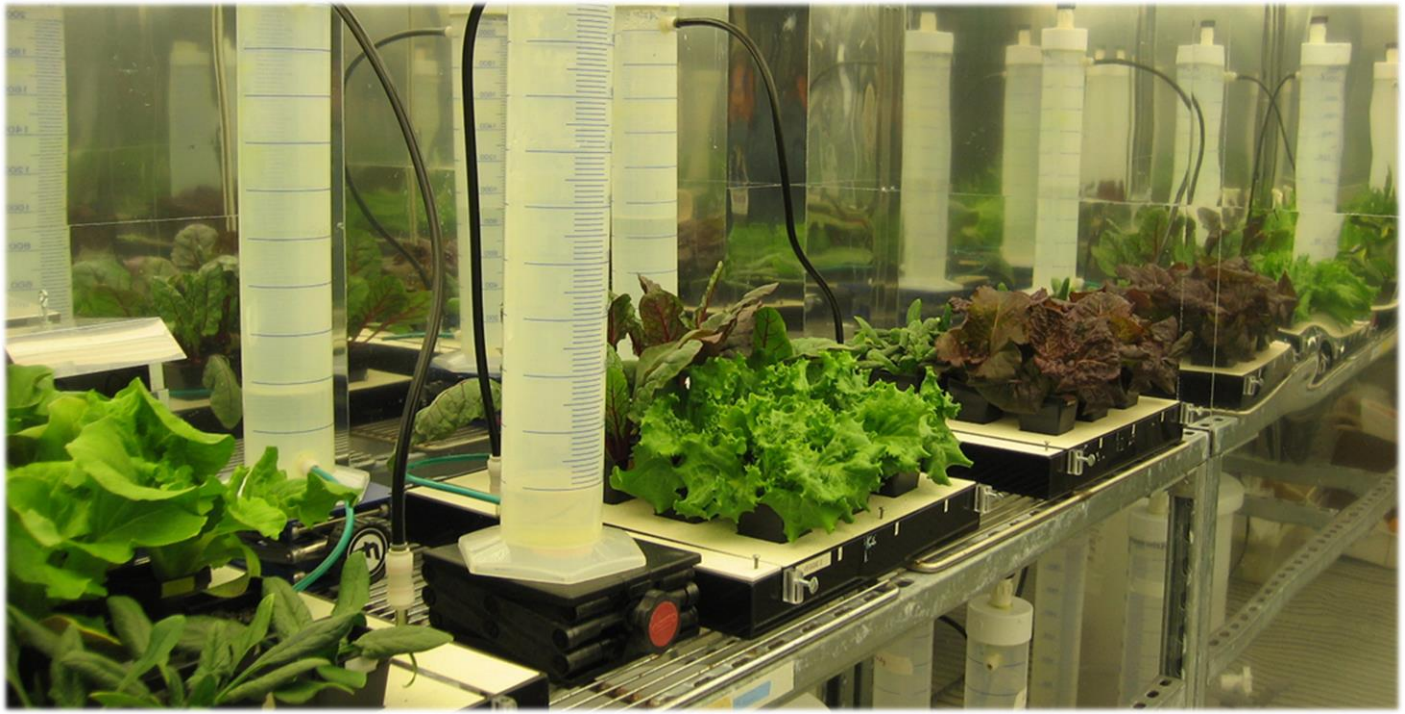
Veggie plant chamber currently on ISS in the Columbus module.

Planned Project Progression

- Selection of top candidate crops based on preliminary studies
- Ground studies with four light treatments and three fertilizer treatments
- Down-selection to the top fertilizer treatment per crop and the top two light treatments
- Veg-04 flight test of leafy green crop under two light treatments (using Veggie Plant Chamber)
  - Crop growth, nutrient and microbial assays on orbit and on ground
  - BHP analysis of impact of crop growth on crew
  - Organoleptic assessment of crop flavor on ISS
- Veg-05 will be similar for dwarf tomato

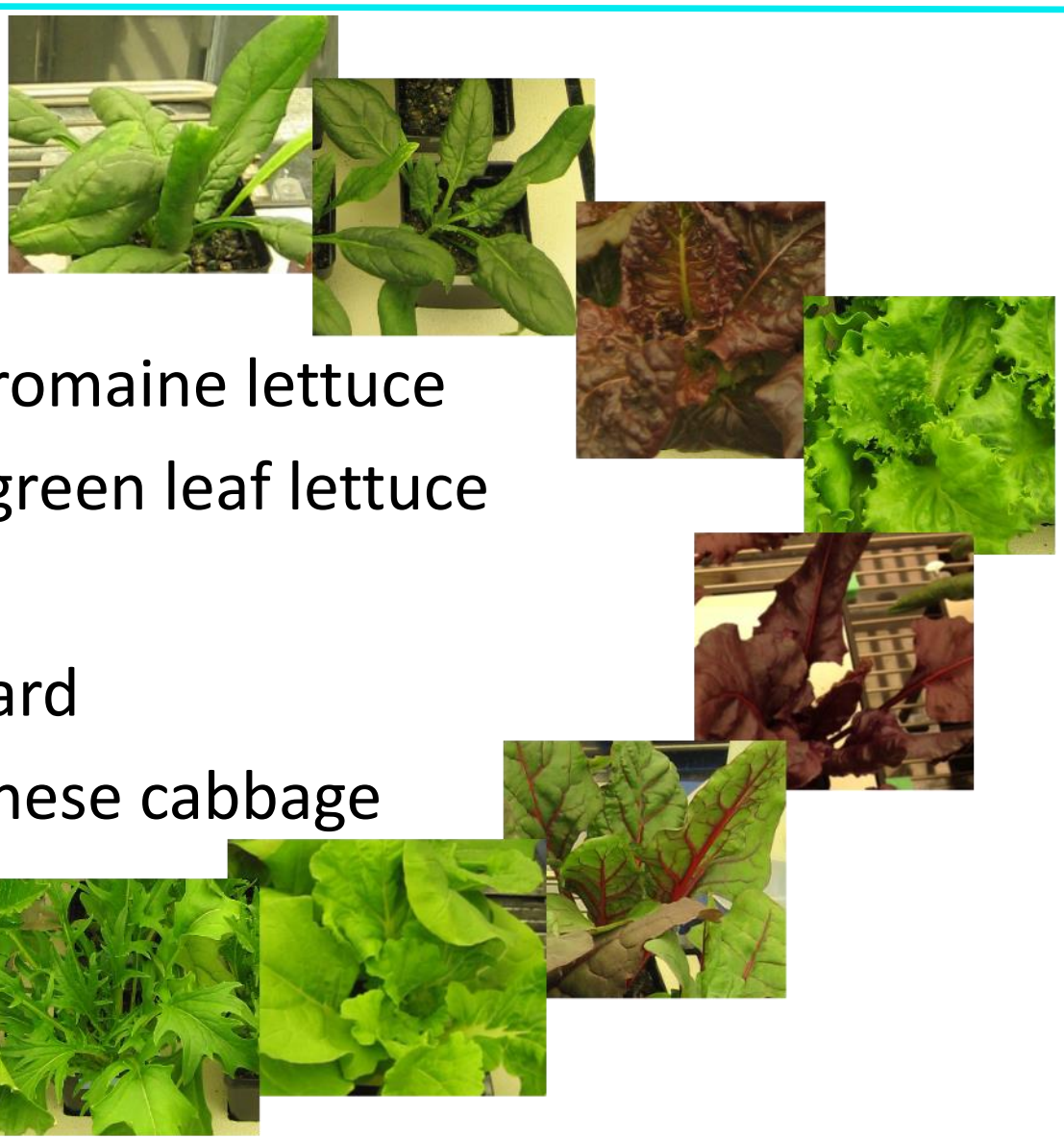
Preliminary Growth Studies

Plants were grown in a controlled environment chamber at NASA's Kennedy Space Center, with environmental conditions set to mimic those on ISS (Temperature, RH, higher CO_2, Light Intensity (but not color)).



Leafy Greens - Candidates

- ‘Tyee’ spinach
- ‘Flamingo’ spinach
- ‘Outredgeous’ red romaine lettuce
- ‘Waldmann’s dark green leaf lettuce
- ‘Bull’s Blood’ beet
- ‘Rhubarb’ Swiss chard
- ‘Tokyo Bekana’ Chinese cabbage
- Mizuna



Dwarf Tomato - Candidates

- ‘Red Robin’ tomato
- ‘Sweet ‘n’ neat’ tomato
- ‘Mohamed’ tomato
- ‘Patio Princess’ tomato
- ‘Tiny Tim’ tomato
- ‘Tumbler’ tomato

Selection Criteria Overview

- Horticultural factors
  - Germination, ease of growth, amount of growth (food), plant size and growth habit
- Dietary factors
  - Percent dry matter
  - Elemental Factors - Composition of key elements (K, Fe, Ca, Mg)
  - Nutrient Factors - Beneficial phytonutrients (Vitamin K, Lutein, Zeaxanthin, Antioxidants, Lycopene (t))
- Organoleptic factors
  - 9-pt Hedonic Scale: Overall taste, Appearance, Color, Flavor, Texture, Bitterness (g), Aroma (t)
  - 5-point Just About Right Scale: Crispness, Tenderness (g), Sweetness, Tartness, Juiciness (t)

(g) = greens and (t)= tomatoes

Top Candidates

- Leafy greens

'Tokyo Bekana' Chinese cabbage

- Dwarf tomato

'Red Robin' Tomato

Plant Testing

- Red and Blue LED light & Fertilizer testing with top leafy green (two 28-day trials) and tomato (one 90-day trial)
  - Testing at KSC, Purdue
  - Four light regimes assessed:
    - 90% Red (R): 10% Blue (B), 70% R: 30% B, 50% R: 50% B, split treatment of ¾ 90%:10% + ¼ 50%:50%
- Three fertilizer release treatments assessed:
    - 100% 180-day release, 66% 180 d: 34% 100 d, 50% 180 d: 50% 100 d
    - 18-6-8 formulation for leafy crop, 14-4-14 for tomato
- Plants assessed for growth and nutrient content

Preliminary Results – Chinese Cabbage

- Growth differences in response to light and fertilizer with interaction likely

- Faster release fertilizer showed stronger growth under light conditions with increased red. Best yield was with 90% red and 50% of 100-day release fertilizer.
- Observed yellowing stress responses to growth conditions
- Currently studying stress sources and mitigation strategies

Preliminary Results – Tomato

- Growth and fruit yield differ in response to light & fertilizer

- Faster release fertilizer produced fewer tomato fruits under high blue conditions and more fruits under a split treatment. The best yield was observed with high red (90%) and 100% of the 180-day release fertilizer.
- Crop also demonstrated some stress responses
- Nutrient analysis underway

Space Food Safety Component

- Hazard Analysis and Critical Control Point (HACCP) Plan
  - Assess risks
  - Evaluate operating parameters
  - Set controls to mitigate risk
- Task involves:
  - Assessment of crop microbiology
  - Working to develop standards for space-grown produce
  - Working with stakeholders to implement regular crew consumption

Baseline Chinese Cabbage Data

Traditional Single Harvest

	Harvest (g)	Harvest (cfu/g)	
Cabbage	Plant FM	APC	Y + M
Plant A	6.3	<DL	441
Plant B	10.1	172	<DL
Plant C	15.1	154	77
Plant D	7.9	27	<DL
Plant E	12.7	<DL	57
Plant F	24.1	<DL	326

Cut-and-come-again 1st harvest

	Harvest 1 (g)	Harvest 1 (cfu/g)	
Cabbage	Plant FM	APC	Y + M
Plant A	15.45	58,500	<50
Plant B	7.10	950	<50
Plant C	3.93	200	<50
Plant D	3.61	<50	<50
Plant E	---	---	---
Plant F	11.96	150	<50

NASA standard for non-thermostabilized food is:

Aerobic Plate Count less than 20,000 CFU/g for a single sample

Yeast and Mold less than 1000 CFU/g for a single sample

- Cut-and-come-again Plant A had APC levels higher than NASA standard
- Seed-borne *Aspergillus niger* fungus was noted on two leaves as black spots
- Mitigation step is a precautionary sanitizing step

Harvested Chinese cabbage was found to be generally acceptable for consumption

Behavioral Health Component

- A highest priority stressor anticipated for a long duration mission is lack of sensory stimulation due to isolation and confinement
- Plants have potential countermeasure benefits:
  - Dramatic visual relief
  - Growth and development provide cues to time passing
  - Tending plants can be relaxing
  - Fresh vegetables for flavor and texture dietary variety
  - Scents, colors and textures augment environment
- Flight approach:
  - Profiles of mood
  - Veggie-specific Questionnaires with Visual Analog Scales to minimize time required
  - Open-ended optional questions

Next Steps

- Second Veggie chamber to be deployed to ISS – summer 2017
- Custom software to be uploaded to both chambers
- Development of new water delivery system
- Growth tests in new analog water delivery
- Establish if supplemental fertilizer can mitigate plant stress
- Institutional review board approval for Veg-04 and Veg-05
- Plan for some percentage of produce consumption in Veg-04 and Veg-05 (if mass measurement available on ISS)

Thank you!

- Matthew Mickens
- Previous team members :
  - Alexandra M. Whitmire
  - Robert Ploutz-Snyder
- Florikan
- Crop Selection (KSC):
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  - Jeff Richards
- Veggie and Veg-04/05 team
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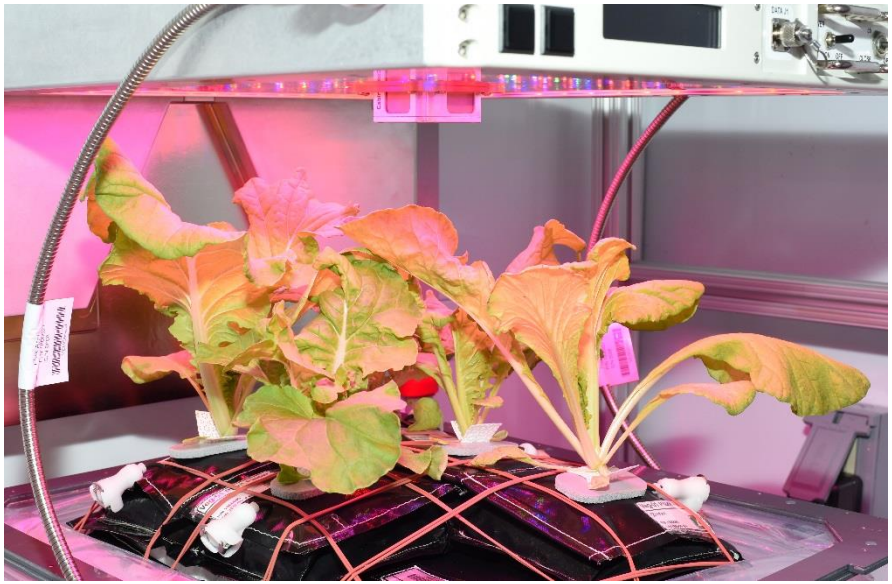

'Tokyo Bekana' Chinese cabbage growing in Veggie

VEGGIE
Vegetable Production System

Questions?